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A TECHNICAL AND OPERATIONAL COMPARISON OF GEOGRAPHIC INFORMATION SYSTEMS AS APPLIED TO THE CANADIAN FOREST INDUSTRY

BY

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A TECHNICAL AND OPERATIONAL COMPARISON OF GEOGRAPHIC INFORMATION SYSTEMS AS APPLIED TO THE CANADIAN FOREST INDUSTRY

MARCH, 1989

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The material was researched, written and produced by Reid, Collins and Associates. Great care was taken to present the material in a clear, factual manner. We encourage current and potential users to contact vendors for further information or clarification on presented material.

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ABSTRACT

A TECHNICAL AND OPERATIONAL COMPARISON OF GEOGRAPHIC INFORMATION SYSTEMS AS APPLIED TO THE CANADIAN FOREST INDUSTRY

From December, 1988 - January, 1989, Reid, Collins and Associates conducted a technical and operational comparison of Geographic Information Systems as applied to the Canadian forest industry. Of 84 surveys sent, 46 were returned complete; however only 40 were returned in time for presentation in the report. Where possible, respondents were contacted in order to clarify feature definitions. Trends and directions in this technology were identified through vendor and user interviews. Few vendors are actively advancing the science and technology of GIS, the majority preferring to follow industry leaders. Product support and longevity is questionable for many vendors, as pursuit of increasing the installed base supercedes user support efforts. Very few vendors are directing research and development efforts to those concerns commonly identified by the GIS community. The survey results are valuable to potential users of the technology, as a single step in the acquisition process, as well as current users who are concerned with where the technology is heading.

1.0 INTRODUCTION

In late 1988, Reid, Collins and Associates undertook a major survey of Geographic Information Systems available to the Canadian forest industry. At first, only those products which were directly marketed to Canada were considered, but with the advent of freer trade with the United States, the survey was expanded to encompass that market segment as well.

In an initial search for vendors, over a hundred were identified. A judicious "thinning" process reduced this list to 84 potential respondents. To increase the response rate, many of these vendors were contacted by phone prior to sending the survey form.

One aspect of this project involved identifying trends and directions in the technology. Numerous follow-up contacts were made with certain vendors in order to determine their thoughts and concerns on this topic. Several user groups were interviewed (with most input obtained from our own clients' experiences) to help identify issues which most concerned them.

Of the 84 surveys sent out, 40 were returned with an enthusiasm expected from groups servicing the public. Many of these responses included detailed product literature and technical specifications. Six of these were from educational or research oriented institutions. Of the non-respondents, 15 were no longer in operation or had relocated to unspecified locations; eight were from universities where such research initiatives are typically transferred among disciplines making contact difficult; 13 chose not to respond for a variety of reasons: the most common being a perception of product unsuitability for forestry/natural resource applications. There was one respondent who declined to allow publication of product information in this report. One other respondent agreed to be removed from the survey when further contact established that the product was not a true GIS.

Eleven vendors did not respond in time for inclusion into this report, but their response is most appreciated and has been drawn upon in the identification of trends and directions in this technology. Late respondents were included in the vendor/respondent list (Appendix I), if possible, prior to the publishing deadline.

It is important to realize that this survey does not represent a comprehensive benchmark of vendor product offerings. Rather, the results were compiled such that a potential user can identify several systems which meet his or her unique requirements, and then follow a comprehensive methodology for narrowing the field. Since GIS technology is constantly evolving, readers should be aware that significant changes will undoubtedly occur to the list of features any one vendor may claim to have. This survey should be used only as a single preliminary step in the selection of GIS products.

2.0 RESULTS

2.1 Support

Software technology, and GIS technology in particular, is advancing at an accelerated pace. New algorithms are constantly being developed and refined which promise to increase the flexibility, accessibility and efficiency of GIS applications. For many organizations, there is no time for keeping up to date with the technology. It is the responsibility of the vendors to advance the technology and inform their user base of the availability of these advancements. It is the responsibility of the user base to assist the vendors in identifying development and improvement requirements. This interaction between vendor and user is the basis for the importance of the support component of this study.

The buyer should beware of a vendor who will agree to sell a GIS without a support or maintenance agreement in force. A maintenance agreement which does not include at the very least telephone support and regular software updates/enhancements is a guarantee of certain GIS obsolescence. The purchase of a GIS should not signal the end of a relationship between the vendor and the user, but the start of an on-going close working relationship.

One sure sign of successful GIS implementation is when the demand for use of the system far exceeds optimistic projections. Heavy demand by a wide variety of users will require close communication with the vendor for two reasons:

1) the need to increase the computing and user-access capacity, and
2) the need to start using the GIS for applications beyond "mapping" and toward "strategic decision aid".

It is at this point that the users interact with the vendor to improve the systems and add enhancements to meet their particular needs.

In the absence of a written and accepted support/maintenance agreement, the system will soon fall along the wayside because of poor software performance due to out-dated software, poor response to software "bugs", and no response to specific user needs. It doesn't take long for a GIS to become rejected under these conditions.

All vendors of purely commercial products are offering fairly comprehensive support and maintenance plans. The only exception to this are the institutional offerings, which are intended primarily for other research and development institutions which typically employ in-house staff capable of handling all support and maintenance requirements.

The quality of the support provided by the vendor is as important as the amount and extent of the support. This measure can only be determined through direct contact with the vendor, contact with other users of the product of interest, or through consultation with an unbiased consultant or third party.

The entire issue of support and maintenance can be indirectly tied to product/vendor longevity in the GIS marketplace. Many vendors are devoting much of their effort toward marketing in order to increase the installed base of systems. Vendors may become over-extended due to their marketing efforts and the established user base is usually the first to suffer. A good sign to look for in the vendor is the actual number of qualified staff actually directing the product development (related to focus and motivation). A larger, well-balanced organization may be more stable and the "resource pool" available is always much larger than for small, regionalized firms.

2.2 System Overview - Spatial

Geographic features have traditionally been represented for analysis in two-dimensional analog models (maps). The inherent inefficiencies in storage, retrieval and updating these two-dimensional models has resulted in the popularity of GIS and Computer Assisted Mapping (CAM) systems (Peuquet, 1984). Two other types of spatial data models have evolved for storing image data in digital form (a requirement of computer based systems such as GIS and CAM). In a "vector" system, each entity on the map becomes one logical record in the digital file, and is defined as strings of "X" and "Y" coordinates. Spatial relationships must be either explicitly recorded or computed. "Tesselation" or "raster" models represent the logical alternative to the vector models. Here, the basic data unit is a unit of space for which entity information is explicitly recorded. A good illustration of this concept is satellite imagery information which is contained in a standard size grid element or pixel. A number of variations of the raster model exist, referred to as "irregular tesselation" or "quadtree" models.

The distinction between "raster" (or tesselation) and "vector" geographic information systems is fast becoming blurred. Many of the respondents to the survey are offering products which are capable of switching between both types of data structures, or to some hybrid data model between the two.

Vector data structure-based GIS excel at "linear" analyses such as network analysis, transportation modeling, or basic mapping functions. Raster data structure-based GIS excel at overlay processes and have a particular distinct advantage in dealing with remotely sensed digital data.

There is a distinct long-term trend toward raster data structures in the GIS community (Tomlinson, 1986). This is a result of the overwhelming presence of remotely sensed digital data, ever increasing hardware processing capability, and advances in data handling and analysis algorithms and methodologies. Analysis of the survey responses indicates that the majority of vendors have not yet realized the importance or significance of this trend. A significant number of them are offering vector-only GIS products. On the positive side, almost all vendors emphasized the importance of having remote sensing interface capabilities for their products in the near future.

It is important to remember that a decision to implement either a raster or vector GIS should be tied closely to the types of analyses most commonly performed and the source of the data to be used by your organization. In Canada, much of the resource information has already been transferred from conventional remote sensing formats (aerial photographs, satellite imagery) to vector format (maps) (Poiker and Crain, 1984). Examples of this include maps such as NTS 1:50 000, NTS 1:250 000, TRIM, Soil Survey, etc. Because of this, the requirement for a raster-based GIS is not as pronounced as in some countries which do not have this "map resource" available for data input or simply cannot wait for the mapsheets to be prepared and validated. Translating raster images to vector format may be important in order to obtain high quality output. Unfortunately for many organizations, the mapping capability of a particular GIS becomes the most critical consideration in the purchasing decision, overshadowing the much more important and useful aspects of strategic resource planning applications. In many cases, a GIS is purchased solely on the basis of the high quality output and screen images. More emphasis must be given to the integrity, security, and source of the data used in the problem solving process. Increasing competition from various resource user-groups will increase the attention given to these data concerns.

Concern for validity of the data will arise as the recognition of environmental aspects of natural resources increases. Detailed record keeping may not be enough to legally justify courses of action taken by resource users. Justification will have to be performed before any action is taken and responsibility for data validity and integrity will rest with the user as well as the owner of the data.

2.3 System Overview - Nonspatial

There has been considerable development in the area of data management methodologies. The dominant trend for data manipulation and storage systems is toward relational and distributed relational models, which have eclipsed the older hierarchical and network data models (Date, 1987). In 1985, mathematician E.F. Codd defined 12 rules which must be met in order for a database management system (DBMS) to be considered truly relational. Because most microcomputer database products on the market today do not meet half of the rules, they cannot be considered fully relational (Finkelstein, 1987). With the relational model, the design of the database structure can be developed separately from the design of the processes that manipulate the data. In this way, the data can be considered to be in a "generic" form relative to the analyses which are performed, resulting in increased data integrity and security as well as lower application development costs. The advent of these technologies as well as the recent availability of fourth generation (4GL) and fifth generation (5GL) languages means decreased costs for application development and maintenance.

The introduction and acceptance of Structured Query Language (SQL) means standardization and portability of applications across a wide range of hardware and operating system platforms. Any SQL-based data manager meets at least seven of Codd's rules (Finkelstein, 1987).

For many non-GIS applications, DOS-based database packages are extremely popular. Most of the PCDOS-based GIS systems are using these products, but as the majority of these indicated they will be moving toward UNIX as an operating system platform, the popularity of the relational database managers will increase substantially. This is due to the fact that the "upper-end" DBMS packages (ORACLE, INGRES, INFO, etc.) are optimized for the "upper-end" operating systems (UNIX, VMS, MVS, etc.). For the most part, vendors seem to be using any number of database managers with no particular trend toward any single product. This would indicate a reluctance to exclude market share by not supporting the popular database management packages. Several

respondents indicated the use of a proprietary database management system - essentially a system which is not sold separately from the GIS. Most of these systems also provide some kind of link to other commercial database managers. The reliability and efficiency of these links may be questionable and any potential user should look closely before purchasing.

An important consideration in the acquisition decision should be the manner in which the DBMS is linked with the spatial component of the GIS. Through vendor interviews, we have found three basic structures which the industry follows for the most part. Conceptually, they are presented in the following diagrams:

FIGURE 1

FIRST LEVEL GIS STRUCTURE

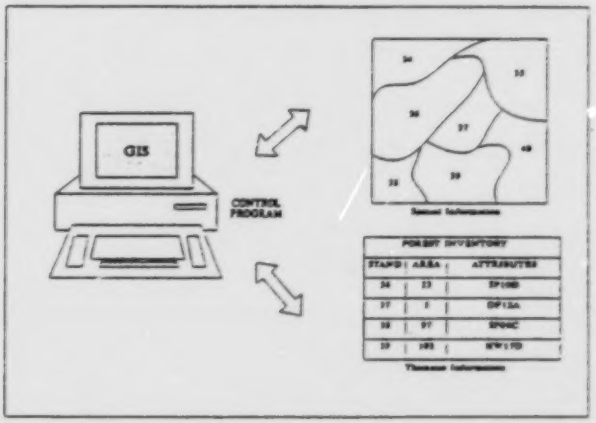


FIGURE 2

SECOND LEVEL GIS STRUCTURE

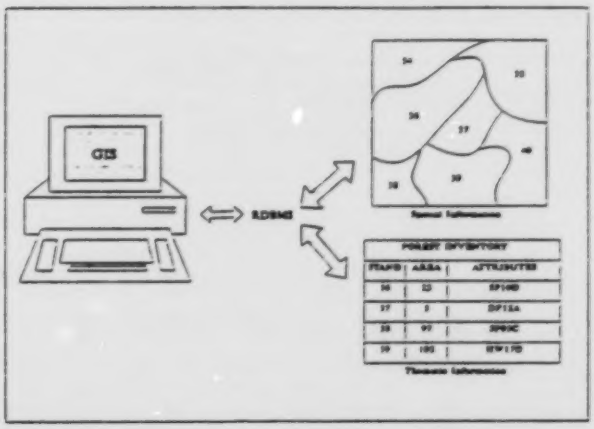
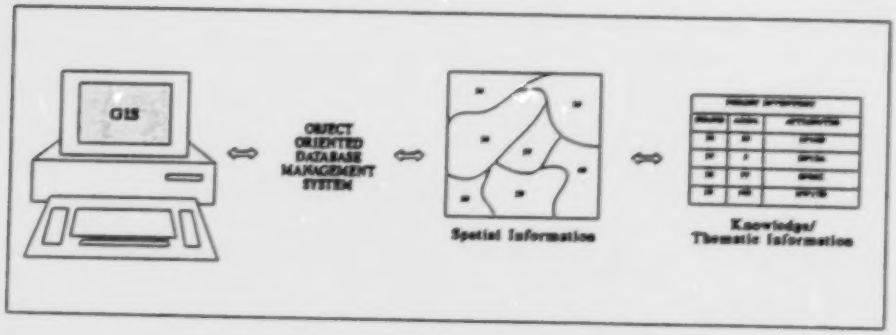


FIGURE 3

THIRD LEVEL GIS STRUCTURE



The majority of GIS can be classified in the first level (Figure 1). In this case, the DBMS is used separately from the spatial component. On one hand, this allows the vendor to substitute virtually any DBMS into the GIS framework at little cost and effort. However, since the spatial data is stored completely external to the DBMS, there exists data integrity concerns. Several GIS are found in the second level (Figure 2). Here, the DBMS is used to control the spatial component, without actually storing the coordinates. This tightly integrated environment ensures data integrity and security without sacrificing processing efficiency. To date, we have found only one GIS using the third level (Figure 3). This advanced environment uses an object-oriented DBMS to manage graphical/symbolic features as well as the knowledge (including attributes) about them.

A decision to acquire a GIS from any of these three levels should depend on the organization's long-term application needs. The first two levels are adequate for mapping and inventory-type projects. The second level should be the starting point (with the third level being ideal) for more analytical-type projects.

2.4 User Interface

If time is money, then this area arguably contains the most important features of a GIS. A good user-interface can substantially decrease the time required to get the GIS operating at full production, thereby decreasing the payback period on the initial investment. A "poor quality" or difficult to understand user interface may kill your organization's initial enthusiasm faster than any other technical feature of the system. Novice users can quickly become intimidated by

unforgiving syntax and complicated menu systems. Of course, the training course provided by the vendor can do much to alleviate this problem, but for most organizations, the cost of sending all potential users to a course is prohibitive. A more common scenario is have one to three staff members attend the training courses, with the idea of transferring the knowledge gained to the rest of the group.

A problem lies in the initial application of GIS technology in most organizations. Many GIS installations neglect addressing issues which will yield the full benefits of GIS: strategic resource planning. The basic automated mapping and inventory applications typically form the bulk of initial applications. Of course, there are benefits to be derived from computerizing the manual processes involved in inventory and mapping, but the organization must not lose sight of the planning and analysis components. For this type of application, the user-friendliness of the system is not the overriding concern. Only a specific technical group within an organization is typically assigned these types of functions, and none of these are management or planning personnel.

Extending availability of GIS to the management and planning groups within an organization will yield the full benefits of the technology. The advancements in database management systems, artificial intelligence applications, and program development environments (fourth generation languages, SQL) help in bringing the technology up to the level of the user. The natural language interface allows a user to concentrate on the semantics of their particular problem without spending an unreasonable amount of effort on the syntax of the decision-aid. By concentrating on semantics, problem solving can be done on a more conceptual level, thereby increasing the amount of work performed as well as the accuracy of responses (assuming a great deal of accuracy is lost in the translation between user and technician in lower-level operations).

All respondents appear to be concerned about the quality of this area of their product. Of particular interest may be the availability of products in the Apple Computer environment, which is known for its extremely powerful and friendly user interface. Workstation products also provide a very friendly user interface, particularly with the addition of "windowing" software.

One extremely important aspect of the user interface is the availability of user-defined macros and menus. With this feature, applications can be designed such that minimal training is required in organizations with high personnel turnover rates. The interface can be modified specifically for each application and for each user if required.

An interface to a lower level programming language (such as FORTRAN, Pascal, C, etc.) allows greater flexibility, and in some cases, efficiency of operations. Many processor-intensive applications will run much faster when translated to a lower level language. With the increasing processing power of hardware the need for this lower level language interface is decreasing rapidly.

2.5 Data Entry/Loading

Almost all users have an interest in both the data loading and entry capabilities of a GIS. As the number of organizations acquiring GIS or computer assisted mapping (CAM) capability grows, more data becomes available in digital form. This requires that systems have the capability of loading data from many different standard file formats. Most users also require a manual data entry capability in order to capture data specific to their resources and desired applications. This manual data entry capability is also important for capturing data not in digital form (e.g. digitizing maps).

A number of digital data exchange formats have been developed, primarily for the exchange of a particular dataset such as the United States Geological Survey data. Currently, a "generic" data exchange format that is accepted industry-wide does not exist. The use of any of these existing databases will require the support of the pertinent exchange format. Given the number of exchange formats it would be almost impossible for a single system to account for all of the possibilities. Most vendors are willing and capable however, of providing the programming services in this area as part of the initial purchase.

The most common method of manual data capture is the digitizing table. The capture of data from this source involves the generation of "X" and "Y" coordinates using a cursor or similar pointing device. The other primary data capture process is through a stereoplotter. This differs from the digitizing table in that a "Z" coordinate is captured along with the "X" and "Y". The support of a digitizing table is mandatory for any GIS, however the support of stereoplotter input is only necessary when applications requiring direct entry from aerial photographs are being considered. As with the data exchange formats, most vendors are also willing to develop interfaces to new devices.

The development of interfaces to input devices and support of data exchange formats should be expected from the vendor as an element of customer support. Hence, the current support of particular devices and data exchange formats should not form a large component of GIS evaluation prior to direct dealings with the vendor. In the end however, the failure or unwillingness of a vendor to support an exchange format or device should preclude the use of that system if no reasonable alternatives are found.

2.6 Data Editing/Manipulation

Every user who maintains their own database will require comprehensive data editing and manipulation capability. This capability is of prime importance as much of the expense associated with operation of a GIS is centred around data entry and editing. A strong editing facility is important in achieving high productivity for editing and data entry. This facility needs to be evaluated by the presence or absence of features and just as importantly, the ease of use of those features.

Most of the surveyed systems appear to have a fairly comprehensive editing capability in terms of features they support. The differences between the data editing capabilities of the systems will lie in the efficiency, the user interface associated with those features, and the ease of assembling the editing procedures into a systematic process.

Forestry databases are typically quite large, contain complex data and include polygon, arc and point data types. Efforts spent entering and editing this data reduce the value of the GIS because less effort tends to be devoted to developing applications and using the GIS as a planning tool. These factors demand that the editing and entry process be evaluated carefully and alternatives be considered for the future. Some of these options include links to image analysis systems and scanning technologies. Although these two options are currently not applicable to most forestry GIS installations (due to financial and technical reasons), their future impact should not be ignored.

The importance of a strong editing function cannot be over-emphasized as it will minimize the time allocated to database maintenance and data entry and free more resources for application development.

With respect to the data manipulation capability of any particular GIS, questions and concerns should be directed to the overall structure or link between the spatial and thematic/attribute components of the system. As discussed above, there seems to be three basic levels of structure to the many systems (weak link between spatial and DBMS component, control link between DBMS and spatial component, and object-oriented DBMS), and any purchase decision must include consideration of intended applications. Only then can the tradeoffs between data integrity and support of popular DBMSs be fully analyzed.

2.7 Data Analysis/Output

The analytical capabilities of a GIS enable it to be used as a strategic planning tool. The use of the system in this manner provides the long-term payback on the investment in GIS. Output capability is very important but it tends to overshadow other GIS capabilities because it is the one concrete product to which a layperson can relate. Resource managers and planners are beginning to realize the need to understand the methodologies used to arrive at computer-aided solutions.

One of the most basic analytical features which is of interest to most users is overlay capability. As the sophistication of the user increases, more complicated analytical features such as network analysis, contiguity analysis and 3-dimensional perspective views are required. The support of all these analytical features varies greatly from one system to another. Some of the systems support a great variety of analytical features applicable to all data types while other systems tend to concentrate on features associated with the analysis of one particular data type. One or the other does not necessarily reflect a better system however, the systems with a wider variety of analytical capabilities will be suitable for more users.

The output capability of GIS needs to be evaluated both in terms of graphic and text display. The DBMS-type reporting capability can often be overlooked due to the "sexiness" of the graphic output. The type of graphic output desired in terms of detail, accuracy, and cartographic quality will determine the required output features as well as the suitability of a raster-only system. Most systems provide vector quality maps, however these must be evaluated in terms of cartographic quality, especially for larger scales. The intended uses of the maps need to be considered as well. A planning level map is distinct from an operational level map in terms of resolution and cartographic requirements. The DBMS reporting facility is vital because it can provide the detail not always available in a map. It must also be realized that a GIS will most often be used to generate a standardized forestry planning/operations map containing forest

polygons along with a stand summary. The detailed data used to compile that summary is not shown on the map but often must be associated with the forest polygons. This can either be done by generating "ad-hoc" specialty maps or producing a textual report that coincides with the standard forestry map.

Support of electrostatic plotters is extremely important for production environments where many graphic products are generated. Complicated maps can take several hours to plot on even the fastest pen plotters available.

While graphic output is important, its importance can be overrated. It is often forgotten that the report or map may only be displaying meaningless data due to faulty data entry, editing or analysis.

3.0 GIS TECHNOLOGY TRENDS AND DIRECTIONS

Many of the features presented in the survey are fairly static in the sense that what is implemented by a vendor today may change in the future. In order to add value to this presentation, a number of issues were raised with vendors which allow us to assess the state of the technology with respect to what the GIS community expects.

Minimizing system obsolescence should be a key objective in the acquisition phase. In order to minimize the risk of purchasing a system which is heading toward obsolescence, you should be well aware of where each vendor is heading with their product and how this direction coincides with where your organization, as well as computer technology, is heading.

It is very important to remember that methodologies used by managers and planners are constantly evolving in order to meet the requirements of the increasingly competitive environment in which we operate. GIS is starting to play an important role as the need for accurate and timely information, as well as robust analytical methods, increases. Technology trends are driven by this need to improve the quality and timing of management decisions. These improvements are made possible, in part, by advances in computer hardware, operating systems, computer software, and management science (or in how problems are solved).

3.1 Computer Hardware

The directions in computer hardware technology are toward lower cost and more powerful processing capabilities. The distinction between microcomputers, minicomputers and mainframe computers is blurred by the introduction of workstation products, supermicrocomputers and superminicomputers. In the distance looms such advances as parallel processing, 64-bit processors (i.e. 80486 CPU), and even an "80586" processor. Parallel advances are seen in the 68000 series of processors as well as new "reduced instruction set computing" (RISC) processors. For some time now, software and operating systems have been the limiting factor in computer installations utilizing these hardware technologies.

The product development objective stated by the majority of GIS vendors is to increase the availability of their products over the widest range of hardware platforms possible. The intent is to minimize system obsolescence by maximizing hardware independence. Availability on as many hardware platforms as possible substantially increases market potential for the vendor. Hardware

independence is also good for users as well: freedom from "proprietary" hardware almost always translates to reduced costs.

In most cases however, the hardware component itself is not the major barrier to increasing availability. Most of the problems, and therefore the development costs, of porting application software to another machine is due to the incompatibility of operating systems. Unfortunately for the end-user, these development costs are absorbed into the purchase price. As stated above, there are also advantages for the end-user when this goal of hardware/operating system independence is achieved. Hardware forms a major cost component of a GIS both directly, with the up-front purchase, and indirectly through personnel required for system maintenance. Hardware independence increases the number of alternatives for the purchaser and therefore allows a greater chance of positioning GIS into the overall management systems of the organization. System maintenance is then distributed over a larger user-group within the organization, decreasing operating costs substantially.

3.2 Computer Operating Systems/Environments

There has been considerable effort in the past few years to define an industry standard operating system which will be available on a wide range of hardware systems. While a true industry standard has not yet been fully agreed to, UNIX is emerging as the dominant choice. UNIX is a versatile operating system developed at AT&T Bell Laboratories in 1969 (Hunt, 1986). This multi-user, multi-tasking operating system is currently available on micro, mini and mainframe computers and has been adapted to a wide variety of hardware products. UNIX (or any one of the adaptations) was developed as an alternative to the expensive proprietary operating systems developed by individual hardware vendors. In the past, Digital Equipment Corp. (DEC) hardware required a proprietary operating system - VMS - which was not transferrable to other hardware products. International Business Machines Corp. (IBM) was in the same position with its variety of proprietary operating systems. Both of these major hardware vendors have recently announced the availability of UNIX-derived operating systems for their hardware (ULTRIX for DEC and AIX for IBM). In the GIS world, the importance and popularity of UNIX is growing steadily. This operating system was more popular with the survey respondents than any other system, including PC-DOS. For those vendors offering products for the PC-DOS environment only, almost all indicated a movement toward UNIX in the near future. For users of GIS technology and those considering acquisition, UNIX offers a means of realizing the full potential of the powerful hardware products such as the new 80386 microcomputers and workstation products. This potential

includes full memory addressing capabilities, running multiple applications concurrently, and increasing accessibility to the machine through the multi-user and networking capability.

Distributed processing has only recently become accepted by the computer community. Pressure from the larger user base has resulted in a relaxing of the restrictions that "central processing" thinkers have placed on the availability of computer resources. This trend has placed further pressure on application software developers to make use of this type of environment.

3.3 Artificial Intelligence

Regardless of these hardware and operating system advancements, application software is still the real limiting factor. A lot of the lag is the result of extreme competition between software vendors, constantly evolving hardware and operating systems (like trying to hit a moving target), and in some cases, poor project management by software vendors for delivering quality products on schedule.

Some recent advancements do offer real promise. The field of Artificial Intelligence (AI) has been active for over twenty years but has only recently evolved into commercial application areas. AI is the subbranch of computer science dealing with the development of intelligent computer programs (Hunt, 1986). These intelligent programs can solve problems, learn from experience, understand language, interpret visual scenes, and, in general, behave in a way that would be considered intelligent if observed by a human. While this area is fairly theoretical and may seem to be removed from practical consideration, there are some very real benefits in integrating AI techniques in how we use computers in our problem-solving efforts. The most commercial of these techniques involves the development and application of "Expert Systems". These are computer programs which are designed to simulate the problem-solving methods or behaviour of an expert in a specific, narrow domain.

AI has been identified in the scientific literature as being one of the most promising fields for advancing the technology of GIS (Lolonis and Armstrong, 1988; Maggio, 1987; Friedl, Estes and Star, 1988). Many of the respondents indicated interest or knowledge of this field, but only a few are actually applying AI techniques in their product development strategy.

The user-community is fast becoming aware of the potential benefits of this technology. Demand for information is being met through organizations and journals devoted to the topic as well as increasing attendance at AI forums and workshops at GIS-related symposia.

3.4 Remote Sensing and Image Analysis

Forestry databases are dynamic in nature because of the ever changing resource and the activities of man. There is a constant demand for up-to-date information on the current status of the resource. While the database management capabilities of a GIS can provide the management and output of data required to meet user demands, it is the input of data in a timely fashion that creates a bottleneck and causes difficulties for the user. Current manual aerial photograph data collection techniques are costly, slow and labour intensive. Remote sensing and image analysis technology promises the potential for reducing the time between data collection and input. Many problems still remain with the application of remote sensing to forestry especially at the operations level, however many survey respondents foresee the benefits of this technology and are working towards integrating their systems directly with it or with systems designed exclusively for image analysis.

3.5 Management Science

Integration of GIS technology with forest management and planning has resulted in several changes in the way problems are approached and solved.

Many of the field data collection techniques are being modified in order to accommodate GIS-based forestry operations. Since this technology has the potential of managing much more information than ever before, we are seeing increased amounts of data being collected from the field. Hand-held data recorders as well as remote sensing instruments facilitate the increased data flow.

A greater variety of analytical methods are becoming available to coincide with the increasing processing power of computers as well as the increased data flow. There is increased interest in using GIS to perform forest planning on an area-basis rather than on the traditional strata-basis as a result of these changes.

Like it or not, computer technology, and especially GIS, is changing the way forest managers and planners operate. Because of this, it is extremely important for these groups to understand the current state of the technology, and to be aware of where it is heading.

4.0 SUMMARY

Throughout the analysis of the survey responses and user interviews, a consistent theme was developed. Essentially, the GIS environment consists of three distinct groups: users; vendors; researchers. The research community has identified several aspects of GIS which should be addressed by developers of the technology. There seems to be a fairly close, but scattered tie between the research community and the vendor community. The user community also has ties to the vendor community (through normal user-vendor relationships). What's missing is a closer tie between all groups within this environment.

In the sense that most GIS features are fairly well-developed (except for modifications and "bug" fixes), the "technology" is relatively mature. However, the "environment" is far from mature. Greater emphasis on cooperative and coordinated communication between the three environment groups is required in order to realize maturity. This is beginning through increased interest and attendance at conferences and symposia dedicated to GIS technology.

For the future, the survey analysis indicates that there will be further reductions to the number of vendors in the marketplace. The highly competitive environment, coupled with explosive demand for products and the problems associated with managing small business growth (management and personnel shortages) lead us to believe there is a parallel to the microcomputer market of the early to mid 1980s. In that situation, we saw the emergence of a few industry leaders from a field of "hundreds" of microcomputer vendors. The timeframe for the GIS industry will be longer due to the greater complexity of the technology.

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APPENDICES

APPENDIX I

LIST OF VENDORS/RESPONDENTS

Delta Systems, Inc./DELTAMAP

- Price: $15,000 to $45,000 U.S.
- Distinguishing Feature: "True open architecture that protects customers from costly upgrades/obsolescence as the hardware/database environment changes".
- Research & Development: 15% of gross GIS revenues directed to development of open architecture as well as new functions.
- Computers: HP, SUN, APOLLO, IBM RT, Silicon Graphics.
- Contact: 2629 Redwing Road, Suite 330
  Fort Collins, CO 80526

  (303)226-3283

Strategic Locations Planning, Inc./ATLAS * GRAPHICS

- Price: $450 to $1,200 U.S.
- Distinguishing Feature: "70% of the high end GIS features for one tenth of the price".
- Research & Development: 40% of gross GIS revenues directed to improving internal database capabilities.
- Computers: IBM PC, PS/2.
- Contact: 4030 Moorpark Avenue, #123
  San Jose, CA 95117

  (408) 985-7400

Forest Data Corp./TerraPak

- Price: $12,000 to $25,000 U.S.
- Distinguishing Feature: "A compact integrated system with a query language capable of performing multi-layer map overlays with simultaneous multi-width or concentric zone generation. An entire query process can be executed with a single command."
- Research & Development: 10% of gross GIS revenues directed to development of applications in Forestry, Agriculture and Geology.
- Computers: IBM PC, SUN, PRIME.
- Contact: 150 N. Wiget Lane, #208
  Walnut Creek, CA 94598

  (415) 935-0735

E.S.L., Inc./IDIMS

- Price: $30,000 to $200,000 U.S.
- Distinguishing Feature: "The capability of geographic reference for image processing of multispectral or reconnaissance sensors and integration with other sources of data."
- Research & Development: 2% of gross GIS revenues directed to integration of vector and raster data systems.
- Computers: VAX
- Contact: 495 Jane Drive
  Sunnyvale, CA 94088-3510

  (408) 738-3550

Tydac Technologies/SPANS

- Price: $8,000 to $16,000 U.S.
- Distinguishing Feature: "The strength of SPANS are Modeling and analytical capabilities."
- Research & Development: 45% of gross GIS revenues directed to improving analytical capabilities; point manipulation techniques; vector (topological) capabilities.
- Computers: IBM PC.
- Contact: 1600 Carlin Avenue, #310
  Ottawa, Ont. K1Z 8R7

  (613) 722-7427

Erdas, Inc./CORE

- Price: $10,000 to $45,000 U.S.
- Computers: IBM PC, VAX, PRIME, DATA GENERAL, SUN.
- Contact: 430 10th Street NW - #N206
  Atlanta, GA 30381

  (404) 872-7327

MicroImages/MIPS

- Price: $2,000 to $5,000.
- Distinguishing Feature: "Fully integrated raster/vector system combining image processing and GIS into low-cost, desktop microcomputer product."
- Research & Development: 60% of gross GIS revenues directed to integration of raster/vector; user interface; hardware integration.
- Computers: IBM PC.
- Contact: 932 N. Lakeshore Drive
  Lincoln, NE 68508-1347

  (402) 477-9554

Jet Propulsion Laboratory/IBIS

- Price: $2,000
- Distinguishing Feature: "We have had a GIS raster-based with vector integration since March, 1976."
- Research & Development: Since the Jet Propulsion Lab is a research institution, all GIS related revenues are directed to research and development.
- Computers: IBM mainframe, VAX.
- Contact: 4800 Oak Grove Drive
  Pasadena, CA 91109

  (818) 354-7236

Uni-Graphic Systems, Inc./Geo-Graphics

- Price: under $6,000.
- Distinguishing Feature: "High performance, full featured PC based workstation to be marketed under $6,000, based on industry standards and a simple database structure that ensures connectivity to other hardware and software for specialized applications."
- Computers: IBM PC.
- Contact: P.O. Box 520610
  Salt lake City, UT 84152-0382

  (801) 484-0691

Chefford Canada Ltd./GIMMS

- Price: $500 to $2,000 U.S.
- Distinguishing Feature: "Price and availability across many platforms; quality output."
- Research & Development: 100% of GIS revenues directed to development of user interface, polygon overlaying, 3-dimensional features.
- Computers: IBM PC, APPLE, HONEYWELL, DEC, CDC, PRIME, HP, APOLLO, HARRIS, DATA GENERAL, CRAY, ATARI.
- Contact: #9 Antares Drive, Unit 25
  Napean, Ont. K2E 7V5

  (613) 727-1738

Facility Mapping Systems, Inc./FMS/AC

- Price: $2,700 to $5,400 U.S.
- Distinguishing Feature: "100% within AUTOCAD - no DXF required or needed; seamless interface to DBM."
- Research & Development: 30% of GIS revenue directed to "GIS functionality".
- Computers: IBM PC, MacIntosh II, SUN.
- Contact: 38 Miller Avenue, #11
  Mill Valley, CA 94941

  (415) 381-1750

Universal Systems Ltd./CARIS

- Price: start at $9,600 U.S.
- Distinguishing Feature: "Support of full topology within a 3-dimensional environment."
- Research & Development: 35% of GIS revenue directed to incorporating computer-assisted mapping/GIS principles into user defined applications; (incorporating software, hardware and network technology).
- Computers: VAX, UNISYS, SUN, TEKTRONIX.
- Contact: 270 Rookwood Avenue
  Fredericton, NB E3B 2M2

  (506) 458-8533

Pamap Graphics Ltd./PAMAP

- Price: $5,000 to $45,000 U.S.
- Distinguishing Feature: "quality of software; platform flexibility; customer support."
- Computers: IBM PC, VAX, DATA GENERAL, INTERGRAPH.
- Contact: 301 - 3440 Douglas Street
  Victoria, BC V8Z 3L5

  (604) 381-3838

Micro-Logic D'Applications/TIM

- Price: $6,600 U.S.
- Distinguishing Feature: "user friendly".
- Research & Development: 20% of GIS revenue directed to increasing ease of use, lower price and increased capacity.
- Computers: IBM PC, SUN.
- Contact: 625 Avenue President Kennedy, #903
  Montreal, PQ H3A 1K2

  (514) 845-7004

Land Management Information Centre/EPPL7

- Price: $400 to $500 U.S.
- Distinguishing Feature: "Will run on virtually any PC, and is very inexpensive and yet powerful; considering the cost, inexpensive site licence."
- Research & Development: 50% of GIS revenues directed to development of new capabilities, commands, tools.
- Computers: IBM PC.
- Contact: 300 Centennial Building
  658 Cedar Street
  St. Paul, MN 55155

  (612) 296-1211

Environmental Systems Research Ins/ARC/INFO - PC ARC/INFO

- Price: $ 3,600 to $ 15,000 CAN. (PC)
  $15,000 to $150,000 CAN.
- Distinguishing Feature: "open architecture; sophisticated application development environment; programming language-AML."
- Research & Development: 35% of GIS revenues directed to analysis and modeling capabilities; user interface; data conversion; remote sensing integration; hardware independence.
- Computers: IBM PC, IBM RT, HP, APOLLO, DATA GENERAL, SUN, VAX, PRIME.
- Contact: 12 Water Street, Suite 300
  Vancouver, BC V6B 1A5

  (604) 682-4652

Kork Systems, Inc./KORK

- Price: $5,000 to $28,000 U.S.
- Distinguishing Feature: "Transaction processing of GIS data; rapid adhoc queries with preprocessing."
- Research & Development: 30% to "editing".
- Computers: VAX, IBM PC.
- Contact: 6 State Street
  Bangor, ME 04401

  (207) 945-6353

Hunter and Associates/HUNTER GIS

- Price: $1,000 to $15,000 U.S.
- Distinguishing Feature: "Consultants in the fields of engineering and environmental/natural science management."
- Research & Development: Directed to "topological (vector) processing, fully integrated with RBASE for DOS".
- Computers: IBM PC.
- Contact: 1121 Woodridge Center Drive, #170
  Charlotte, NC 28217

  (704) 525-8620

Sammamish Data Systems, Inc./GEOSIGHT

- Price: $3,950 to $5,000 U.S.
- Distinguishing Feature: "Oriented to the unique requirements of market research."
- Research & Development: 40% of GIS revenues directed to development of functional enhancements to new applications.
- Computers: IBM PC.
- Contact: P.O. Box 70382
  Bellevue, WA 98007

  (206) 867-1485

Geogroup/GEO-BASEMAP

- Price: $15,000 to $25,000 U.S.
- Distinguishing Feature: "software designed to accommodate wide range of mapping and planning applications; ease of use; connection to other applications (appraisal, building permits, billing)."
- Computers: UNISYS, planned UNIX and MS DOS.
- Contact: 2560 North Street, #319
  Berkley, CA 94710

  (415) 549-7030

VL Systems, Inc./VANGO

- Price: $11,250 U.S.
- Distinguishing Feature: "VANGO is a fully integrated product that can perform the entire range of CAD functions as well as advanced geographic information management and display with the highest data precision available."
- Research & Development: Directed to maintaining an integrated multiuser system; also supporting the GIS related needs of the civil and municipal engineer.
- Computers: VAX.
- Contact: 9 Corporate Park
  Irvine, CA 92714-5124

  (714) 660-8855

Mapping Information Systems Corp./MAPINFO

- Price: $750 U.S.
- Distinguishing Feature: "Our price/performance sets us apart. For $750 on inexpensive hardware, an agency/company can benefit from a surprisingly powerful, easy to use and learn GIS package."
- Computers: IBM PC.
- Contact: Hendrick Hudson Building
  200 Broadway
  Troy, NY 12180

  (518) 274-8673

University of Washington/ODYSSEY

- Price: $700 U.S.
- Distinguishing Feature: "Source code distribution for instruction and research; robust, fast polygon overlay processor with cluster handler prism map."
- Research & Development: University organization, R & D directed to "temporal data structure/spatial indexing/user interface/error models".
- Computers: VAX, MASSCOMP, IBM mainframe.
- Contact: Department of Geography DP-10
  Seattle, WA 98195

  (206) 543-5870

Pennsylvania State University/SPIRAL

- Price: public domain.
- Distinguishing Feature: "primarily developed for research purposes."
- Research & Development: University organization, directed to "making interactive on VM/CMS; adaption to microcomputer; putting on PRIME computer".
- Computers: IBM mainframe.
- Contact: School of Forest Resources
  208 Ferguson
  University Park, PA 16802

  (814) 865-1602

DBA Systems/GRASS

- Price: $950 U.S.
- Distinguishing Feature: "GRASS is essentially public domain. U.S Government Agencies (Soil Conservation Service, Park Service, Forest Service) are very interested in using GRASS on many levels. GRASS is also extremely portable."
- Research & Development: Directed to "image processing capabilities and improved user interface".
- Computers: SUN, MASSCOMP, AT&T, MacIntosh, Tektronix.
- Contact: 10560 Arrowhead Drive
  Fairfax, VA 22030

  (703) 591-0800

IBM Corp./GFIS

- Price: $50,000 to $80,000 U.S.
- Distinguishing Feature: "IBM's GIS systems interface with all of our standard information systems software. We provide Enterprise Integration with a GIS database that models the real world. our system can be used for inventory, analysis and management decision making. Our database systems are standard systems which have excellent reliability and security."
- Computers: IBM System 370 family such as 9370s, 43XX, 309XS.
- Contact: 3700 Bay Area Blvd
  Houston, TX 77058-1199

  (713) 335-3217

Geovision Corp./GEOVISION

- Price: n/a
- Distinguishing Feature: "strong GIS System Architecture".
- Computers: VAX, SUN, IBM (AIX).
- Contact: 1600 Carling Avenue, #350
  Ottawa, Ont. K1Z 8R5

  (613) 722-9518

ITD Space Remote Sensing Center/GRASS

- Price: $950 U.S.
- Distinguishing Feature: "140,000 lines of source C code; full GIS; digitizing; remote sensing and outputs; very easy to use and learn; many users; accepts standard data formats; great 3D projections; tutorials in manual; sample database distributed with code."
- Research & Development: 50% directed to "more remote sensing modules; RDPMS; CAD-CAM integration".
- Computers: MASSCOMP, MacIntosh
- Contact: Building 1103, Suite 11b
  Stennis Space Centre, MS 39529

  (601) 688-2509

VTA Photogrammetric Consultants/VMAP

- Price: $6,500 to $60,000 U.S.
- Distinguishing Feature: "the ability to interface with remote sensing, photogrammetric, and scanning subsystems; the ability to display stereoscopically and edit scanned images."
- Research & Development: DATA GENERAL, IBM PC, TEKTRONIX
- Computers: DATA GENERAL, IBM PC, TEKTRONIX
- Contact: 480-10655 Southport Road SW
  Calgary, Alta T2W 3M6

  (403) 271-0841

Software Support Ltd./GEOREF

- Price: $7,500 to $60,000 U.S.
- Distinguishing Feature: "The spatial database, GEOREF, is independent of both the graphics engine and the RDBMS. The use of AUTOCAD provides a low cost entry to many users who are already trained in its use. Links to relational databases including DB2 are relatively straight forward programming tasks."
- Research & Development: 25% directed to "improved user interface, mainframe linkages, SAA, distributed data management speed".
- Computers: IBM PC, SUN, IBM AS400.
- Contact: 13220 St. Albert Trail, Suite 225
  Edmonton, Alta T5L 4W1

  (403) 455-9197

Autometric, Inc./MOSS/MAPS

- Price: public domain.
- Distinguishing Feature: "Autometric has been involved with GIS technology for the last 15 years. We are responsible for three complete GIS: AUTOGIS (MOSS), DELTAMAP and MILGIS. Autometric is a government contractor."
- Research & Development: Directed to "government requirements".
- Computers: DATA GENERAL, PRIME, TEKTRONIX, VAX, HP, IBM PC.
- Contact: 1746 Cole Boulevard, #225
  Golden, CO 80401-3210

  (303) 277-1603

Northwest Digital Research/Overlay/Digitize

- Price: N/A
- Distinguishing Feature: "Our proprietary data structure provides efficient storage of large quantities of data and fast access times."
- Computers: HP.
- Contact: Suite 415, Discovery Parks
  3700 Gilmore Way
  Burnaby, BC V5G 4M1

  (604) 437-0044

GeoBased Systems, Inc./STRINGS

- Price: $10,000 to $40,000 U.S.
- Computers: VAX, IBM PC.
- Contact: 4800 Six Forks Road
  Raleigh, NC 27609

  (919) 783-8000

ComGrafix, Inc./MAPGRAFIX

- Price: $8,500 U.S.
- Distinguishing Feature: "MapGrafix provides an easy to use, accessible GIS capability without budget-busting capital investments with the following features: software tailored to capable, low cost micro-system; minimum training; focus of control remains with end user, agency retains control over data capture, storage, interpretation, and retrieval; user-defined, 'Visual What If's' provide a flexible tool for hypothesis testing; flexible graphic display/output options, plotters, laser printers, slide makers, phototypesetters.
- Research & Development: 30% to "maintenance of user-friendliness; development of new spatial analysis procedures; increasing import/export options for sharing files with other mapping systems; user transparent links to SQL databases, AUX, optical storage, and mini-mainframe connectivity".
- Computers: MacIntosh, Apple 32 bit workstations.
- Contact: 7718 N. Berkeley Avenue
  Portland, OR 97203

  (813) 443-6807

Microsolve Corp./Microsolve

- Price: $6,000 to $16,000 U.S.
- Distinguishing Feature: "Integration with attribute database management system, including statistical functions, that permit planners, assessors, and others to exchange data. System is part of a computer assisted mass appraisal package".
- Research & Development: Directed to "networking".
- Computers: IBM PC.
- Contact: 135 Beaver Street
  Waltham, MA 02154

  (617) 894-7271

National Park Service/GRASS/ELAS

- Price: $1,000, public domain.
- Distinguishing Feature: "Multiple cell size database/analyses".
- Research & Development: Directed to "Integration with other systems or system capabilities and peripheral interfaces".
- Computers: MASSCOMP, SUN, IBM 386, MacIntosh, Silicon Graphics, UNIX-BASED HARDWARE.
- Contact: GIS Division
  P.O. Box 25287
  Denver, CO 80225-0287

  (303) 969-2590

Kern & Company Ltd./INFOCAM

- Price: $40000 to $60000 U.S.
- Distinguishing Feature: "Kern provides turnkey systems with integrated on-line connection to analytical stereoplotters"
- Computers: VAX
- Contact: CM-5001 AARUA
  Switzerland

  0041 64 26 4444

Altek Corporation/ALMAP

- Price: $695 U.S.
- Distinguishing Feature: Digitizing and editing software
- Computers: IBM PC
- Contact: 12210 Plum Orchard Drive
  Silver Springs, MD 20904

  (301) 572-2555

Digital Resource Systems Ltd./Terrasoft

- Price: Not Provided by Respondent
- Distinguishing Feature: "Incorporate both raster and vector processing for GIS analysis"
- Computers: IBM PC
- Contact: 402-495 Dunsmuir Street
  Nanaimo, BC V9R-7122

  (604) 753-7122

Prime-Wild Leitz Canada Ltd./System 9

- Price: N/A
- Computers: SUN
- Contact: 513 McNicoll Avenue
  Willowdale, Ont. M2H 2C9

  (416) 497-2460

APPENDIX II

GLOSSARY OF TERMS

GLOSSARY OF TERMS

3-D PERSPECTIVE VIEWS:

A 3-dimensional surface image as viewed from a given location (i.e. from a given distance, height, and direction).

4GL

See Fourth Generation Language.

5GL

See Fifth Generation Language.

ACCURACY:

The degree to which an estimated or measured value conforms, on average, to the actual value. See "PRECISION".

AGGREGATION:

The combination of data or data layers into a composite, typically on the basis of the range of a shared characteristic.

ALGORITHM:

A finite series of often repetitive steps, which defines a procedure for solving a specific problem.

ANALOG (ANALOGUE) IMAGE:

An image in which the magnitude of a physical variable forms the representation of objects. A photograph is an example of an analog image since objects are represented by the "gray scale" of the emulsion.

ANNOTATION:

Any markings on a map which are used for identification or clarification (i.e. markings which describe features but are not in themselves features). Annotation is strictly associated with graphic display and is not linked to the attribute database.

ARC:

A geometric entity containing and connecting a series of points, and typically with a "node" defining each terminal. Arcs represent spatial objects which are linear in nature, and are often associated with attributes. In addition, arcs form the boundary of polygons (area features). May also be referred to as a Line, a Chain, a String, or an Edge. Arcs are strictly associated with vector-based systems.

ARTIFICIAL INTELLIGENCE:

A branch of science which combines cognitive psychology with computer science in an attempt to emulate human reasoning with computers. Artificial Intelligence programs deal with symbolic information (e.g. words) and follow nonalgorithmic approaches to problem solving.

ASPECT:

The azimuth of the maximum slope of a geographic area.

ASPECT RATIO:

The numerical ratio of an image's width to its height. This term is used primarily in the description of video displays.

ATTRIBUTE:

A distinctive, descriptive characteristic associated with a spatial feature. A forest type may be associated with a polygon, or an arc may have an attribute describing road class.

BATCH PROCESSING:

Execution of a series of software commands in the absence of direct intervention by an operator.

BENCHMARK:

A reference which serves as a standard in the evaluation or comparison of related systems.

BINARY TREE:

Describes a class of hierarchical data structures based on the principle of recursively decomposing an image into mutually exclusive halves until a region is homogeneous, or a specified level has been reached.

BOOLEAN OPERATIONS:

Logical operations that apply the rules of Boolean Algebra. The results take on only one of two values, often represented as TRUE/FALSE or 1/0. The basic Boolean operations are AND, OR, NOT, and XOR.

BUFFERING:

Identifying, classifying, and differentiating an area on the basis of its distance from a spatial feature. This operation can be applied to points, lines, or polygons, and typically involves the reconstruction of topology. This GIS function has many forestry applications including the establishment of road right of ways, defining operability buffers surrounding streams, or identification of high risk areas surrounding insect infestations.

CAD:

Acronym for Computer Aided Drafting. Often represented as CADD (Computer Aided Design and Drafting).

CAM:

Acronym for Computer Aided Mapping.

CARTESIAN COORDINATES:

A coordinate system in which the location of points in space are given by reference to orthogonal (perpendicular) planes.

CARTOGRAPHY:

The science of map and chart construction.

CELL:

The basic element in a raster representation of spatial elements. Cells are typically rectangular with a defined size and position, and are arranged in a grid format. Features in a raster-based GIS are defined on the basis of cells.

CENTROID:

A coordinate point associated with an area feature (polygon).

CCSM:

An acronym used to describe the topological digital exchange format being promoted by the Canada Centre for Mapping.

CLIPPING:

The creation of a new "mapsheet" in which features outside of a predetermined boundary are permanently eliminated. A useful function for isolating an area of interest to reduce storage and processing requirements.

COGO:

Often used to refer to any set of mathematical tools allowing the conversion of azimuths, distances and angles to coordinates. Specifically refers to the Interactive Coordinate Geometry Analysis System.

COMPILATION:

The conversion of image and tabular data into spatially related component information, either manually or using computer algorithms.

COMPRESSION:

A procedure used to reduce the amount of physical storage space required to store information, or the act of using such a procedure. Compression techniques are most effective on datasets consisting of repetitive series.

CONNECTIVITY ANALYSIS:

Identification of spatial objects which are connected by linear objects. The identification of mature forest stands which are mill accessible given the existing road network, would be a typical forestry application.

CONTIGUITY ANALYSIS:

The identification of specific objects (typically polygons) which share a common boundary or node. A forestry example would be the identification of all mature lodgepole pine stands adjacent to a stand infected with the Mountain Pine Beetle.

CONTOUR LINE:

A line connecting points of equal elevation. May also refer to a line connecting points equal in some other factor, such as annual precipitation.

CONTROL POINT:

A spatial feature used as a reference point by other features. The location of the control point is considered known (to the desired level of accuracy).

COORDINATE FILTERING:

The permanent removal of superfluous coordinates for the purpose of eliminating unnecessary complexity. This function is advantageous for reducing storage and processing requirements. (See WEEDING).

COORDINATE SYSTEMS:

Numerical methods of representing locations on the earth's surface. Examples include UTMs, or latitude and longitude.

CORRIDOR ANALYSIS:

See "BUFFERING".

COVERAGE:

Includes all of the spatial and associated attribute information relating to a given area of interest. Other terms used include MAPSHEET and THEME.

CURVATURE:

The rate of change in slope (second derivative of elevation). Indicates the convexity/concavity of a surface.

DATABASE:

A collection of related information. A GIS database maintains both spatial and attribute information related to geographic objects, although they may be stored in separate and distinct databases. The sophistication of the link between the spatial and attribute information is largely a result of how each database is managed. Some GIS software may use a different database management system for the spatial data than for the attribute data.

DATABASE MANAGEMENT SYSTEM (DBMS):

See "DBMS".

DATABASE STRUCTURE:

The specific manner in which elements of data are organized in the database. (See "BINARY TREE", "QUADTREE", and "RELATIONAL".

DBMS:

Acronym for Database Management System. Refers to all of the tools of access which allow a user to create, delete, query or update a database. May be referred to as the database "user interface".

DEM:

Acronym for Digital Elevation Model. See "DIGITAL TERRAIN MODEL".

DFX:

A digital graphics exchange format specific to AUTOCAD.

DIGITAL IMAGE:

An image represented by a matrix of "pixels", each of which is assigned a number indicating the "brightness value". See "IMAGE ANALYSIS", "SPECTRAL RESOLUTION", "SPATIAL RESOLUTION", "RADIOMETRIC RESOLUTION".

DIGITAL TERRAIN MODEL:

An analytical method for describing and manipulating 3-dimensional spatial data. May be used for forestry applications such as cutblock layout in areas of high aesthetic value. Most existing DTMs lack the sophistication for complex engineering applications.

DIGITIZING:

The digital encoding of compiled map data.

DIME:

Acronym for Dual Independent Map Encoding System, a topological data structure used by the United States Bureau of the Census.

DISSOLVE:

A GIS function which provides the ability to merge adjacent polygons on the basis of specified rules relating to common attributes. The result is new, larger polygons with attributes which are newly assigned, or derived from the source polygons. This function is useful in the generation of new themes, such as the classification of a forest by growth type from a detailed stand mapsheet.

DISTRIBUTED PROCESSING:

Allows some less intensive processing to be de-centralized onto intelligent workstations (having a local CPU and disk storage), as opposed to all processing occurring on the central host. The advantages of distributed processing are:

1) Reduction of the processing load on the host computer, allowing better response to applications requiring intensive processing.
2) Increased flexibility in the organization and allocation of computer resources.

DISTRIBUTED RELATIONAL DBMS:

A relational database management system in which data may reside at multiple sites on a variety of hardware platforms. A requirement of such a system is that the actual physical location of the data is transparent to the user.

DLG:

Acronym for Digital Line Graph Format, a cartographic exchange format proposed by the United States Geological Survey.

DMDF:

A digital exchange format utilized by the 1:20 000 mapping program in Alberta, and upon which the B.C. TRIM program is based.

DRAPING:

A display technique allowing planimetric information to be overlaid on 3-dimensional perspective models. A typical forestry example would be displaying soil stability polygons on a terrain perspective.

DTM:

See "DIGITAL TERRAIN MODEL".

EDGE MATCHING:

A GIS function which allows merging of adjacent mapsheets into a single mapsheet, by automatically joining lines and polygons across boundaries, and eliminating resultant "sliver" polygons.

EXPERT SYSTEM:

A computer program that uses symbolic knowledge to simulate the behaviour of human experts. The three basic features of an expert system are the user interface, the inference engine, and the knowledge base. See "ARTIFICIAL INTELLIGENCE".

EXPORT:

Converting a system's internal data to a format which allows the data to be used by external systems. See "IMPORT".

FEATURE:

An object about which a GIS maintains spatial and attribute information. Features are represented by geometric entities (points, lines, and polygons). Examples would be wellsites, roads, or forest stands.

FOURTH GENERATION LANGUAGE (4GL):

A high level, non-procedural language, most commonly used for database applications. The basic unit operated on may be an object (comprising many elements), rather than a single element as in Third Generation Languages (eg FORTRAN). The primary advantage of 4GL's is increased productivity in application development and maintenance.

FIFTH GENERATION LANGUAGE (5GL):

Computer languages which extend the concepts utilized in 4GL's by providing a better natural language interface, and enhanced capability in the manipulation of objects. 5GL's are generally utilized in Artificial Intelligence applications.

GENERALIZE:

Reducing the complexity and detail represented by a coverage. Involves decreasing the resolution of features, or the resolution of the attributes which describe features. An example would be aggregating stand polygons into conifer, deciduous, or mixed types only.

GENERATE:

An exchange format specific to ARC/INFO GIS.

GEOCODING:

A process which allows the position of geographical features to be defined relative to a reference grid.

GEOGRAPHIC INFORMATION SYSTEM:

All elements and procedures comprising a system for the capture, maintenance, manipulation, analysis, modelling, and presentation of spatially linked information. GIS is often used (incorrectly) to refer solely to the software component of such a system.

GEOPROCESSING:

The use of computers to process digitally stored spatial and associated attribute data.

GIS:

See "GEOGRAPHIC INFORMATION SYSTEM".

IGDS:

Acronym for Interactive Graphic Design Software (INTERGRAPH), and used to refer to the format used by this format.

IMAGE ANALYSIS (DIGITAL IMAGE PROCESSING):

The transformation of a digital image for the purpose of enhancing the image, removing distortions to restore a correct representation of objects, or for extracting quantitative information.

IMPEDANCE:

A "cost" which is assigned to a particular course of action. In a networking analysis aimed at minimizing travel time, a road with a low speed limit would be assigned a high impedance.

IMPORT:

Converting data stored in an external format to a systems internal format. An example would be converting a mapsheet in Standard Interchange Format (SIF) to the internal format used by ARC-INFO.

INFERENCE ENGINE:

The control mechanism in an Expert System, regulating the reasoning processes used by the program.

INTERFACE:

The hardware/software link that allows communication between different hardware/software, or allows a user access to computer resources.

KNOWLEDGE BASE:

A domain-specific collection of facts and rules (heuristics) which is critical to the construction of an Expert System. Expert Systems are often referred to as "knowledge-based systems".

LABELS:

Descriptive information which is associated with a graphic feature. Labels are constructed from information stored in the attribute database and are automatically updated with the database. The link to the attribute database differentiates labels from annotation. Labels may be referred to as "intelligent annotation".

LAYERS:

Levels of data which, while referring to the same geographic area and related through a common coordinate system, each deal with a specific "theme". One layer may represent roads, another waterways, and a third forest stands. Other terms often used are LEVEL, OVERLAY, or THEME.

LINE SMOOTHING:

A GIS function which adds points to a line to improve the cartographic quality.

LINE THINNING:

See "WEEDING".

MACDIF:

Acronym for Map And Chart Data Interchange Format.

MAINTENANCE AGREEMENT:

A written agreement between a software/hardware vendor and a purchaser, which specifies the continuing support which will be provided (typically for a fee) to the purchaser by the vendor. Maintenance agreements typically include product query support, as well as provision of enhancements/upgrades developed during the term of the agreement.

MAP EXTENT:

The real-world area which is represented by a coverage or mapsheet.

MODEL:

An abstraction of reality.

NEAREST NEIGHBOR ANALYSIS:

A GIS function which allows for the identification of the features meeting specific attribute requirements, which occur nearest to a specified feature. See "PROXIMITY ANALYSIS".

NETWORK ANALYSIS:

A GIS function which selects the optimal route along linear features. Each feature typically has an impedance (penalty) associated with it, and may have a resource inventory. Network analysis can be used to determine the shortest (or quickest) route between two points, allocate the least-cost resources to a centre, or partition resources between multiple centres subject to resource requirements and total impedance constraints.

NODE:

A distinctive point which is used to define the termini of lines, and which typically forms the basis for the link to attributes. May also be used to relate attribute information to other (i.e. linear or area) features.

OPERATING SYSTEM:

Low-level software which controls the operation of computer hardware, and through which a user and higher level software gains access to the central processing unit and other hardware resources.

OVERLAY:

A GIS function which allows multiple themes (layers, levels) to be merged into a single theme, resulting in a new topology with associated attributes derived logically from the input themes. Raster based systems typically perform overlays more efficiently due to their inherent data structure.

PARALLEL PROCESSING:

The process through which software commands are intelligently directed to more than one central processing unit (CPU), allowing simultaneous processing of multiple instructions from a single program.

PIXEL:

The smallest unit to which information is associated in an image. Each pixel is associated with an area of specified size.

PLANIMETRIC DATA:

Spatial data which can be represented within a single plane (2-dimensional data).

POINT:

A geometric entity having no area or length. May be used to graphically represent "spot" features (eg wells or survey markers), with associated attributes.

POLYGON:

A closed geometric entity used to graphically represent area features with associated attributes.

POLYGONIZATION:

An automatic GIS function which establishes polygon topology from digitized line segments. Allows for faster data entry since polygon topology does not have to be created during digitizing, but can be established later, often through batch processing.

PRECISION:

1) The number of significant digits used to represent floating point data.
2) The consistency of measurements or estimates.

PROFILE ANALYSIS:

Extraction of a planimetric representation or view from a DTM representation or view.

PROGRAMMER'S INTERFACE:

A facility allowing a user to write customized GIS applications in a high level language, with access to the GIS data and functions.

PROJECTIONS:

Methods of representing (mapping) the points of a sphere (e.g. earth) on a single plane.

PROXIMITY ANALYSIS:

A GIS function which identifies all features within a specified distance of other features. See "NEAREST NEIGHBOR ANALYSIS".

QUADTREE:

Describes a class of hierarchical data structures based on the principle of recursively decomposing an image into mutually exclusive quarters (quads) until a region is homogeneous, or a specified level has been reached. This data structure facilitates storage in "tessellation" based systems by allowing cell size to vary across a coverage, providing more detail only where it is required.

QUERY LANGUAGE:

A system of high level commands which allows the user to access a database.

RADIOMETRIC RESOLUTION:

The resolution to which light has been measured in a digital image (e.g. pixel values could range from 0-7, or from 0-15, with a range of 0-15 allowing greater resolution).

RASTER:

A method of representing spatial information in which the coverage is partitioned into a regular pattern of rectangular cells. Each cell is associated with a map feature and the related attributes. Geographic features are defined on the basis of the cells that comprise them. This term refers specifically to a regular pattern of cells and so (strictly speaking) does not apply to systems which use a "quad-tree" or other data structure, although the term is often used to encompass such systems.

RECTIFICATION:

The process of eliminating from an image distortions due to tilt, relief, or other factors.

REDUCED INSTRUCTION SET COMPUTING (RISC):

A concept utilized primarily by "workstation" developers in which the central processing unit (CPU) has a smaller instruction set, which reduces overhead and allows for faster processing.

RELATIONAL DATABASE:

A database management system which conforms to all of the 12 rules of the relational model, constructed by Dr. E. F. Codd. This term has often been incorrectly used to refer to databases which are made up of tables, but which do not conform to the majority of the relational model rules.

RELIEF:

Refers to the variability in elevation over an area.

REMOTE SENSING:

Obtaining information about an object through the analysis of data acquired by a device that is not in contact with the object.

RESOLUTION:

The smallest possible distance between two points such that each is maintained as a separate entity.

ROSTER DATA MODEL:

The Roster model is a generalization of the relational database model, allowing the manipulation of data structures rather than just individual items.

ROTATION:

A geometric transformation which changes the orientation of a feature or group of features.

RUBBERSHEETING:

Automatically adjusting the coordinates of features such that the map features conform to the locations of known control points.

RUN LENGTH ENCODING (RLE):

A data structure which allows the compressed storage of raster data by storing the attribute value once, followed by the number of consecutive cells to which it applies.

SCALE:

The ratio of map distance to the corresponding real-world distance.

SCALING:

The transformation of geometric data through the multiplicative application of scaling factors.

SEED POINT:

See "CENTROID".

SEMANTIC MODELING:

A largely theoretical discipline concerned with the development of database management systems that have the ability to "understand" the "meaning" of the data stored in a database. Based on a set of semantic concepts including entities, properties of entities, and associations among entities.

SIF:

Acronym for Standard Interchange Format, a digital graphics exchange format standardized by several vendors of CADD/CAM systems.

SLIVERS:

A term referring to narrow, elongated polygons, typically created during the digitizing, editing, overlaying, or edgematching of spatial data. Slivers are created when lines representing the same boundary fail to correspond exactly. Such polygons do not represent actual geographic features.

SNAPPING:

An automatic editing facility which intersects two lines when the endpoint of one line is within a specified distance (tolerance) of the second line. This is a necessary feature for "cleaning" errors in digitizing which would prevent proper topology creation owing to "leaking polygons".

SPAGHETTI DIGITIZING:

A method of digitizing which does not require a specific sequence of progression or the identification of line intersections.

SPATIAL RESOLUTION:

The actual area represented by each pixel (or grid square) in an image. The smaller the area represented, the higher the resolution. See "RESOLUTION".

SPECTRAL RESOLUTION:

The width of the frequency band of light that has been measured. See "RESOLUTION".

STEREOPLOTTER:

A device for capturing 3-dimensional coordinates direcly from aerial photographs. See "RESOLUTION".

STRUCTURED QUERY LANGUAGE (SQL):

A system of high level commands which allow a user to access a database. Any database management system (DBMS) which is based on SQL meets at least 12 of Codd's relational database rules.

TESSELLATION:

Refers to a data structure in which spatial objects are represented by a (possibly irregular) matrix of grid cells. Includes raster and quad-tree data structures.

TOLERANCE:

A specified criteria used to select features for snapping, dissolving, etc, during the automatic "cleaning" of data and during the creation of topology.

TOPOLOGY:

The mathematical representation of spatial relationships among geographic entities.

TOPOLOGICAL OVERLAY:

See "OVERLAY".

TRANSLATION:

A geometric transformation involving a linear shift in location.

TRIM:

A digital exchange format for spatial information used by the British Columbia provincial government. Adapted from the DMDF format used in Alberta.

USER INTERFACE:

The manner in which the user interacts with a computer system (hardware and software) in terms of entering commands and receiving responses.

VECTOR:

A geometric entity having both magnitude and direction, and used as a method of storing spatial information. Typically vectors are represented as an ordered pair of points relative to an origin.

WEEDING:

A GIS function which reduces the number of points used to represent a line. Points are eliminated on the basis of a specified density, or to the extent that points occur only when a line changes direction. Reduction of the number of points decreases data storage and processing requirements.

APPENDIX III

FEATURE SUMMARY

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An interface to a lower level programming language (such as FORTRAN, Pascal, C, etc.) allows greater flexibility, and in some cases, efficiency of operations. Many processor-intensive applications will run much faster when translated to a lower level language. With the increasing processing power of hardware the need for this lower level language interface is decreasing rapidly.

2.5 Data Entry/Loading

Almost all users have an interest in both the data loading and entry capabilities of a GIS. As the number of organizations acquiring GIS or computer assisted mapping (CAM) capability grows, more data becomes available in digital form. This requires that systems have the capability of loading data from many different standard file formats. Most users also require a manual data entry capability in order to capture data specific to their resources and desired applications. This manual data entry capability is also important for capturing data not in digital form (e.g. digitizing maps).

A number of digital data exchange formats have been developed, primarily for the exchange of a particular dataset such as the United States Geological Survey data. Currently, a "generic" data exchange format that is accepted industry-wide does not exist. The use of any of these existing databases will require the support of the pertinent exchange format. Given the number of exchange formats it would be almost impossible for a single system to account for all of the possibilities. Most vendors are willing and capable however, of providing the programming services in this area as part of the initial purchase.

The most common method of manual data capture is the digitizing table. The capture of data from this source involves the generation of "X" and a "Y" coordinates using a cursor or similar pointing device. The other primary data capture process is through a stereoplotter. This differs from the digitizing table in that a "Z" coordinate is captured along with the "X" and "Y". The support of a digitizing table is mandatory for any GIS, however the support of stereoplotter input is only necessary when applications requiring direct entry from aerial photographs are being considered. As with the data exchange formats, most vendors are also willing to develop interfaces to new devices.

1.0 INTRODUCTION

In late 1988, Reid, Collins and Associates undertook a major survey of Geographic Information Systems available to the Canadian forest industry. At first, only those products which were directly marketed to Canada were considered, but with the advent of freer trade with the United States, the survey was expanded to encompass that market segment as well.

In an initial search for vendors, over a hundred were identified. A judicious "thinning" process reduced this list to 84 potential respondents. To increase the response rate, many of these vendors were contacted by phone prior to sending the survey form.

One aspect of this project involved identifying trends and directions in the technology. Numerous follow-up contacts were made with certain vendors in order to determine their thoughts and concerns on this topic. Several user groups were interviewed (with most input obtained from our own clients' experiences) to help identify issues which most concerned them.

Of the 84 surveys sent out, 36 were returned with an enthusiasm expected from groups servicing the public. Many of these responses included detailed product literature and technical specifications. Six of these were from educational or research oriented institutions. Of the non-respondents, 15 were no longer in operation or had relocated to unspecified locations; eight were from universities where such research initiatives are typically transferred among disciplines making contact difficult; 13 chose not to respond for a variety of reasons: the most common being a perception of product unsuitability for forestry/natural resource applications. There was one respondent who declined to allow publication of product information in this report. One other respondent agreed to be removed from the survey when further contact established that the product was not a true GIS.

Eleven vendors did not respond in time for inclusion into this report, but their response is most appreciated and has been drawn upon in the identification of trends and directions in this technology. Late respondents were included in the vendor/respondent list (Appendix I), if possible, prior to the publishing deadline.

ABSTRACT

A TECHNICAL AND OPERATIONAL COMPARISON OF GEOGRAPHIC INFORMATION SYSTEMS AS APPLIED TO THE CANADIAN FOREST INDUSTRY

From December, 1988 - January, 1989, Reid, Collins and Associates conducted a technical and operational comparison of Geographic Information Systems as applied to the Canadian forest industry. Of 84 surveys sent, 46 were returned complete; however only 36 were returned in time for presentation in the report. Where possible, respondents were contacted in order to clarify feature definitions. Trends and directions in this technology were identified through vendor and user interviews. Few vendors are actively advancing the science and technology of GIS, the majority preferring to follow industry leaders. Product support and longevity is questionable for many vendors, as pursuit of increasing the installed base supercedes user support efforts. Very few vendors are directing research and development efforts to those concerns commonly identified by the GIS community. The survey results are valuable to potential users of the technology, as a single step in the acquisition process, as well as current users who are concerned with where the technology is heading.

Digital Resource Systems Ltd./Terrasoft

- Price: N/A
- Distinguishing Feature: "Incorporate both raster and vector processing for GIS analysis"
- Computers: IBM PC
- Contact: 402-495 Dunsmuir Street
  Nanaimo, BC V9R-7122

  (604) 753-7122

Prime-Wild Leitz Canada Ltd./System 9

- Price: N/A
- Computers: SUN
- Contact: 513 McNicoll Avenue
  Willowdale, Ont. M2H 2C9

  (416) 497-2460

Vendor Number
SUPPORT
Maint. Fees include updates?
Phone support available?
BBS support available?
3rd Party support available?
Initial training available?
Vendor supplied training?
Training aids included?
SYSTEM OVERVIEW (Spatial)
Vector data structure
Raster data structure
Quad-tree data structure
Other data structure
3-D topology
SYSTEM OVERVIEW (NonSpatial)
Proprietary
dBase III
dBase IV
R:Base
INGRES
ORACLE
INFORMIX
Others available
USER INTERFACE
Keyboard commands
Function-key commands
Screen Menus
Pointing device (mouse)
Digitizer tablet menu
User-defined "macro"
Batch mode command processing
User-defined menus
Dual screen workstation
Single screen workstation
Programmer's Interf
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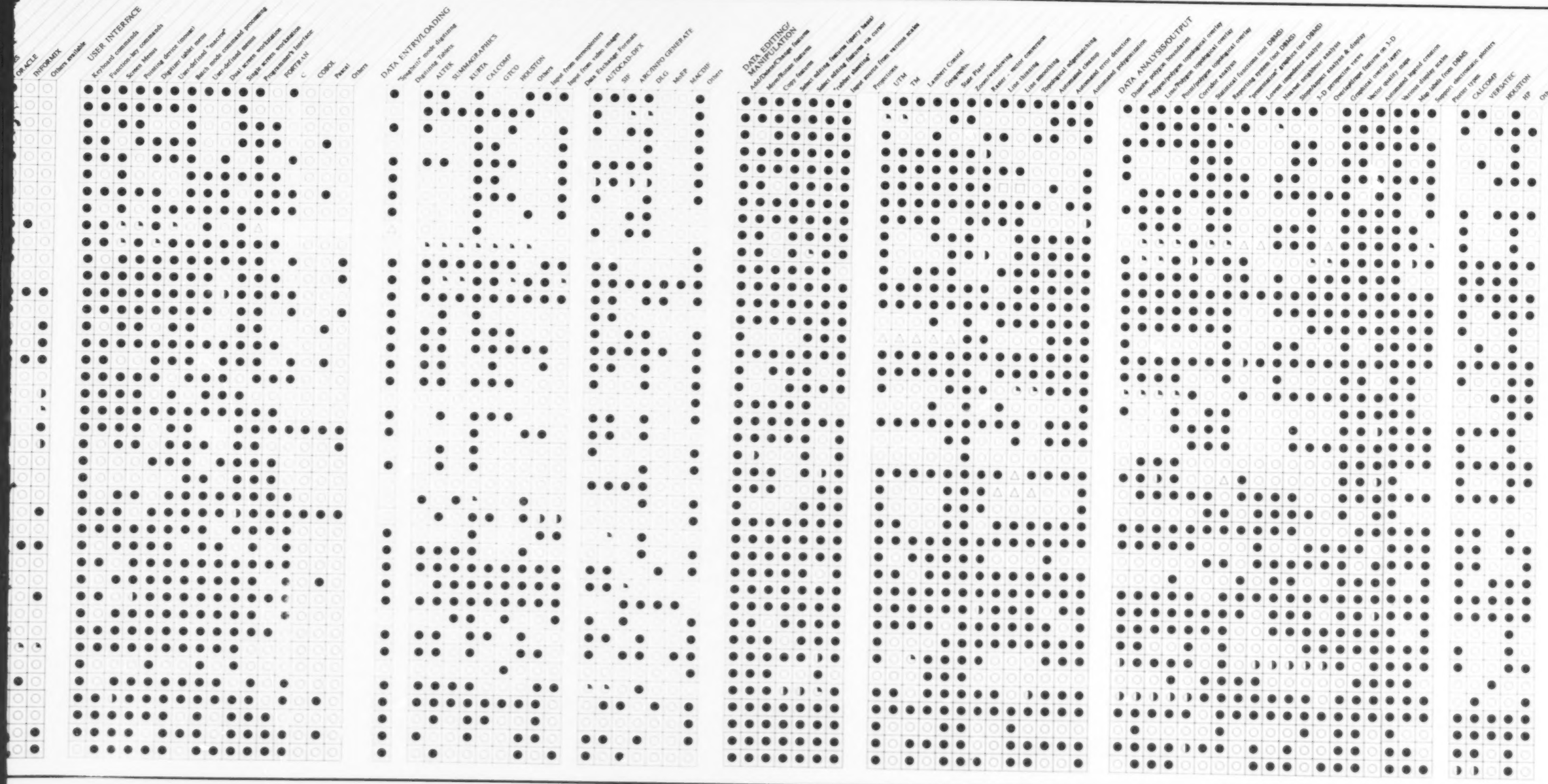
1989 GEOGRAPHIC INFORMATION SYSTEMS SURVEY RESULTS



Compiled by Reid, Collins and Associates

PRODUCT	VENDOR	VENDOR #
ARC/INFO	Environmental Systems Research Institute	16
ATLAS	Strategic Locations Planning, Inc.	2
CARIS	Universal Systems LTD	12
CORE	ERDAS, Inc.	6
DELTAMAP	Deltasystems, Inc.	1
EPPL7	Land Management Information Centre	15
FMS/AC	Facility Mapping Systems, Inc.	11
GEO-BASEMAP	Geogroup	20
GEO-GRAPHICS	UniGraphic Systems, Inc.	9
GEOREF	Software Support LTD	30
GEOSIGHT	Sammamish Data Systems, Inc.	19
GEOVISION	GeoVision Corporation	27
GFIS	IBM Corporation	26
GIMMS	Chefford Canada LTD	10
GRASS	DBA Systems	25
GRASS	ITD Space Remote Sensing Centre	28
GRASS/ELAS	National Park Service	36
HUNTER GIS	Hunter and Associates	18
IBIS	Jet Propulsion Laboratory	8
IDIMS	ESL, Inc.	4
INFOCAM	Kern	38
KORK	Kork Systems, Inc.	17
MAPGRAFIX	ComGrafix, Inc.	34
MAPINFO	Mapping Information Systems Corp	22
MICROSOLVE	Microsolve Corporation	35
MIPS	MicroImages	7
MOSS/MAPS	Autometric, Inc.	31
NULOR	NULOR	40
ODYSSEY	University of Washington	23
OVERLAY/DIGITIZE	Northwest Digital Research	32
PAMAP	PAMAP Graphics LTD	13
SPANS	Tydac Technologies	5
SPIRAL	Pennsylvania State University	24
STRINGS	GeoBased Systems, Inc.	33
SYSTEM 9	Prime-Wild Lietz	39
TERRAPAK	Forest Data Corporation	3
TERRASOFT	Digital Resource Systems	37
TIM	Micro-Logic d'Applications	14
VANGO	VL Systems, Inc.	21
VMAP	VTA Photogrammetric Consultants	29

SYMBOL REFERENCE

- ● Fully Supported/Implemented
- ◑ Supported/Implemented with Restrictions
- ◔ Under Development
- ○ Not Supported/Not Implemented
- △ Not Available
- □ Not Applicable